ON A SOLUTION OF ONE FUZZY LOGIC PROBLEM

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Abstract. In this paper defuzzification method of WABL is investigated, its properties are analyzed. The WABL method is applied to some fuzzy models. The package of applied programs is worked out on the base of proposed algorithms. The obtained in the form of visual- interactive graphs results are compared with knows ones.

Keywords: fuzzy number, defuzzification, averaging representative, waited average based, fuzzy logic.

Fuzzy simulation nowadays is one of the intensive directions of researches in control and decision making fields. Fuzzy simulation, i.e. fuzzy theory-based program models enable to get more adequate results in the field of control of engineering systems. Their application field becomes more and more from year to year: domestic electric equipments, cameras, video cameras, industrial robots and others are converted to fuzzy logic based working principles.

Sometimes to use the defuzzification instead of fuzzy parameters, i. e. exact representative is possible from the point of view of model's adequacy and this considerably simplifies the calculations. There are different defuzzification methods: COA(Center of Area), (Median of Maximum), OWA(Ordered Weighted Average), WABL(Weighted Average Based on Levels) and ets. To use this or other defuzzification method depends on the statement of the problem.

In the paper a new WABL defuzzification method-based logic deduction rules are given and applied to fuzzy regulators.

We first consider WABL defuzzification method. Let the fuzzy number A be given by LR-description, i.e.

$$A = \bigcup_{\xi\in[0,1]} \left(\xi, A^{\xi}\right).$$

Hear $A^{\xi} = \left[L_A\left(\xi\right), R_A\left(\xi\right)\right]$ and $L_A\left(\xi\right) = \mu_{\uparrow}^{-1}\left(\xi\right), \quad R_A\left(\xi\right) = \mu_{\downarrow}^{-1}\left(\xi\right)$. $\mu_{\uparrow}^{-1}$ and $\mu_{\downarrow}^{-1}$ define left and right sides of a fuzzy number correspondingly.

Definition. When we say averaged representative of fuzzy number or WABL aggregation we mean the following quantity:

$$I_W(A) = c_L \int_0^1 L_A(\xi)p(\xi)d\xi + c_R \int_0^1 R_A(\xi)p(\xi)d\xi \tag{1}$$

Where c_L and c_R indicate the importance degree of the left and right hand sides, respectively, by operating on fuzzy members and

$$c_L \geq 0, \quad c_R \geq 0 : c_L + c_R = 1$$

$p\left(\xi\right)$ is the distribution function of importance degrees.

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$P : [0, 1] \to E_+ \equiv [0, +\infty]$ and $\int_0^1 p(\xi)\, d\xi = 1$

We can show that a general form of the function $p(\xi)$ is as follows:

$$p(\xi) = k\xi^{k-1} \tag{2}$$

here $k > 0$.

The properties of WABL defuzzification method.

1. WABL method is more general. For some class of fuzzy numbers we can select the parameters c_L , c_R , and $p(\xi)$ so that the result obtained by WABL defuzzification method coincides with the result obtained by an other defuzzification methods.

2. WABL defuzzification method is additive, i.e.

$$I_W(A + B) = I_W(A) + I_W(B)$$

This method enables to take into account the expert's strategy in a model.

3. If the result of defuzzification doesn't satisfy the experts by changing c_L , c_R , and $p(\xi)$ parameters he may change defuzzification number or slide it arbitrarily to the left or right hand side.

Now give the stages of logic deduction rules based on WABL defuzzification method.

1. Organization of rules base for logic deduction rules;

2. Fuzzification of input and output variables, i.e. construction of fuzzy sets $\mu_{k_i}(x)$, $i = \overline{1, n}$ and $\mu_{l_i}(x)$, $j = \overline{1, m}$ describing the k_i input fuzzy and l_i output fuzzy states;

3. Calculation of validity degree of entrance of $x = \overline{x}$ exact input estimate to the fuzzy input estimates set $\mu_{k_i}(x)$, $i = \overline{1, n}$. Denote this validity degrees by $\overline{k_i}$: $\overline{k_i} = \mu_{k_i}(\overline{x})$, $i = \overline{1, n}$;

4. Defuzzification of l_i output fuzzy subsets by WABL method (determination of $I_W(l_j)$, $j = \overline{1, m}$;

5. Addition of the exact input value of defuzzification results with the coefficients equal to validity degree;

$$I_W = \sum_{i=1}^{n} \sum_{j=1}^{m} \overline{k_i} I_W(l_j)$$

Example. Let's see the functioning fuzzy deduction rules in expert system controlling a fan of room conditioner (see 1, p. 262) . Conditioner's work keeps optimal temperature in the room .

Assume that by changing rotation speed of the fan . we can change the temperature of the room. let's construct the working algorithm of the conditioner step by step. We first give rules base for the working algorithm. Notice that the organization of rules base in a subjective process and depends on the desire of the expert .

Rules base :

1) If the temperature of the room is lover, the rotation speed of a fan is lover;
2) If the temperature of the room is middle, the rotation speed of a fan is middle;
3) If the temperature of the room is higher, the rotation speed of a fan is higher;

As we see there are six fuzzy terms sets in rules base. Three of them: "lower temperature", "middle temperature " and " higher temperature " are input fuzzy parameters; the other ones :"lover speed " , "middle speed ","higher speed " are output fuzzy parameters.

We are to define membership functions for fuzzy subsets determined in fuzzy input value set of temperature and in fuzzy output values set of rotation speed of the fan in defuzzification step of fuzzy variables.

Let's define membership function for the "lover", "middle" and "higher" fuzzy subsets of temperature.

$$\mu_{t_{lower}}(t) = \begin{cases} 1, & t \le 12 \\ \frac{20-t}{8}, & 12 < t < 20 \\ 0, & t \ge 20 \end{cases} \tag{3}$$

$$\mu_{t_{middle}}(t) = \begin{cases} 0, & t < 12 \ ve \ \ t > 30 \\ \frac{t-12}{8}, & 12 \le t < 20 \\ \frac{30-t}{10}, & 20 \le t \le 30 \end{cases} \tag{4}$$

$$\mu_{t_{higher}}(t) = \begin{cases} 0, & 0 < t < 20 \\ \frac{t-20}{10}, & 20 \le t < 30 \\ 1, & 30 \le t < 60 \end{cases} \tag{5}$$

Now let's define fuzzy subsets for output variables. Assume that the rotation speed of the fan varies from 0 and 1000 rot/min. then we'll define for this speed the "lower", "middle" and "higher" fuzzy subsets and their membership functions as follows:

$$\mu_{v_{lower}}(t) = \begin{cases} 1, & 0 < v < 200 \\ \frac{400-v}{200}, & 200 \le v \le 400 \\ 0, & 400 < v < 1000 \end{cases} \tag{6}$$

$$\mu_{v_middle}(t) = \begin{cases} 0, & 600 < v < 200 \\ \frac{v-200}{200}, & 200 \le v < 400 \\ \frac{600-v}{200}, & 400 \le v \le 600 \end{cases} \tag{7}$$

$$\mu_{v_{higher}}(t) = \begin{cases} 0, & 0 < v < 400 \\ \frac{v-400}{200}, & 400 \le v < 600 \\ 1, & 600 \le v < 1000 \end{cases} \tag{8}$$

3. Let's see the process of definition of rotation speed of a fan depending a temperature of the room by fuzzy expert system . Assume the room's temperature is $t = 22^0C$.
The first calculate the degree of $t = 22^0C$ value to fuzzy subset (1) – (3):

$$\mu_{t_{lower}}(22) = 0$$

$$\mu_{t_{middle}}(22) = 0,8 \tag{9}$$

$$\mu_{t_{higher}}(22) = 0,2$$

In this step defuzzificate fuzzy output subset (6) - (8) by WABL method.

Let's write the increasing and diminishing parts in fuzzy set (7) according to levels:

$$L_{\nu_{lower}}(\xi) = 0, R_{v_{lower}}(\xi) = -200\xi + 400$$

Take them into account in (1):

$$I_W(v_{lower}) = (1 - c_L) \int_0^1 (-200\xi + 400)(k+1)\xi^k d\xi \ = \ -200 c_L \frac{k+3}{k+2} -$$

$$- \ 200 \frac{k+1}{k+2} + 400. \tag{10}$$

For fuzzy set (7)-(8) :

$$L_{v_{middle}}(\xi) = 200\xi + 200, R_{v_{middle}}(\xi) = -200\xi + 600,$$

$$I_W(v_{middle}) = c_L \int_0^1 (200\xi + 200)(k+1)\xi^k d\xi + (1 - c_L) \int_0^1 (-200\xi + +600)(k+1)\xi^k d\xi = -400 c_L \frac{1}{k+2} - 200\frac{k+1}{k+2} + 600, \quad (11)$$

$$L_{v_B higher}(\xi) = 200\xi + 400, R_{v_{higher}}(\xi) = 1000,$$

$$I_W(v_{higher}) = c_L \int_0^1 (200\xi + 400)(k+1)\xi d\xi + (1 - c_L) \int_0^1 1000(k+1)\xi^k d\xi = = -200 c_L \frac{2k+5}{k+2} + 1000 \quad (12)$$

Now multiply the averaged representative of input fuzzy subsets l_i by corresponding constants equal to k_i and summarize them:

$$I_W = 0 \cdot I_W(l_{lower}) + 0.8 \cdot I_W(l_{middle}) + 0.2 \cdot I_W(l_{higher}) = 0.8 \cdot 400 + 0.2 \cdot 766 = 473.2 \quad (13)$$

So if temperature will be 22^0C the expert will adopt the rotation speed of a fan 473.2 rot/min.

Each time when we result of logical deduction is required the above mentioned operations are carried out by the same order. In dynamic control systems this sequence is performed periodically.

It each time we'll mark the pair (t, v) in coordinate surface we'll obtain a graph of the dependence of rotation speed.

It was proved that fuzzy logic conditioners provide the less vibration of temperature and saves much electric power. The work of fuzzy logic based systems in dynamic processes is more effective than work of control circuits working on an ordinary thermostat.

The other expert system may determine the rotation speed by another way. But by changing the parameters c_L, c_R and $p(\xi)$ in WABL defuzzification formula. We can arbitrarily change the rotation speed of a fan within its definition domain. The comparing the results of the work of our expert system and the expert system given in [1] with different values of input parameters is shown on the p. 3-4. The optimal temperature to what the temperature of the room tents as a result of air conditioner working is defined by itself system. In our case changing the values of $c_L$and c_R. The optimal temperature of the room may be changed.

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